AATT TO 24

Communications System Architecture Development

for

Air Traffic Management and Aviation Weather Information Dissemination

Agenda

- Task Overview
- Requirements Collection
- Candidate Architecture Concepts
- Functional Architecture
- Current/Near Term Link Definition
- Communication Load Analysis
- Architecture Alternatives
- Transition Schedules
- Gap Discussion
- Summary

AATT TO 24 Team

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AATT TO 24 Team

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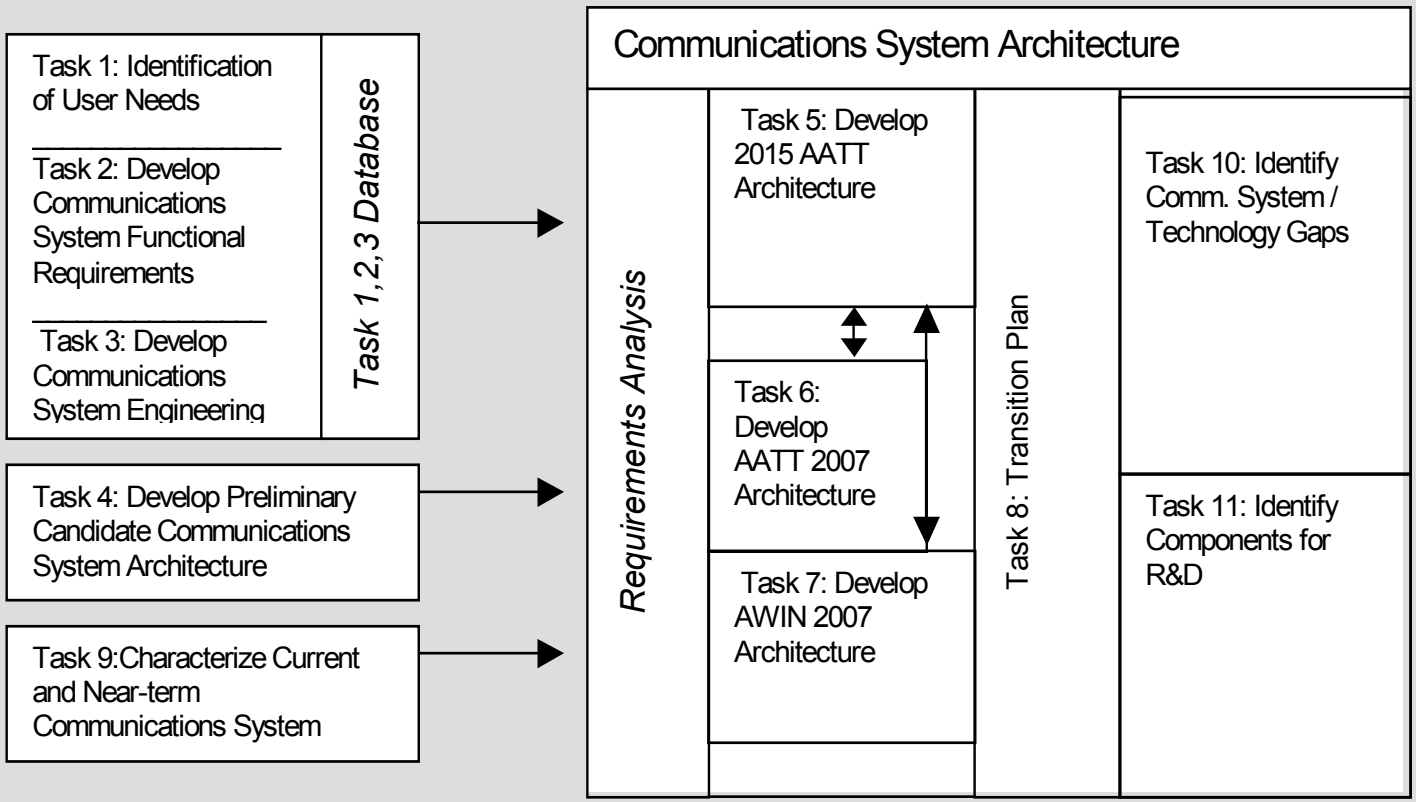
Task 1 Identification of User Needs	**Task 2** Communications System Functional Requirements	**Task 3** Communications System Engineering Requirements	**Task 4** Preliminary Comm. System Architecture Concepts
Task 5 2015 AATT Architecture	**Task 6** 2007 ATM Architecture	**Task 7** 2007 AWIN Architecture	**Task 8** Transition
Task 9 Current Data Links	**Task 10** Communications Technology Gaps	**Task 11** Areas for Research and Development	**Final Report** **May 26, 2000**

Task Relationship



Requirements Collection

Task 1

Identification of User Needs

Task 2

Communications System Functional Requirements

Task 3

Communications System Engineering Requirements

Master Source List

Task 1

FARs
Concept Documents
Industry Reports

Task 2

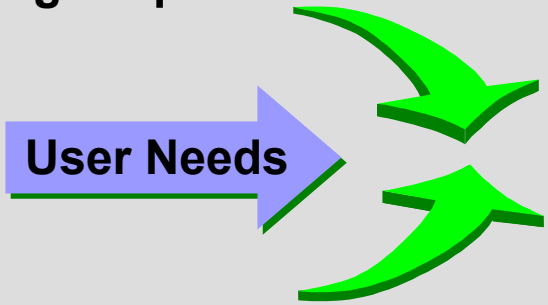
RTCA DO's
FAA Requirements Documents
Consultant Studies and Reports
Concept Documents

Task 3

ATN SARPs
RTCA DO's
FAA Requirements Documents
Consultant Studies and Reports
EuroControl Documents

Data Repository

Engineering Requirements



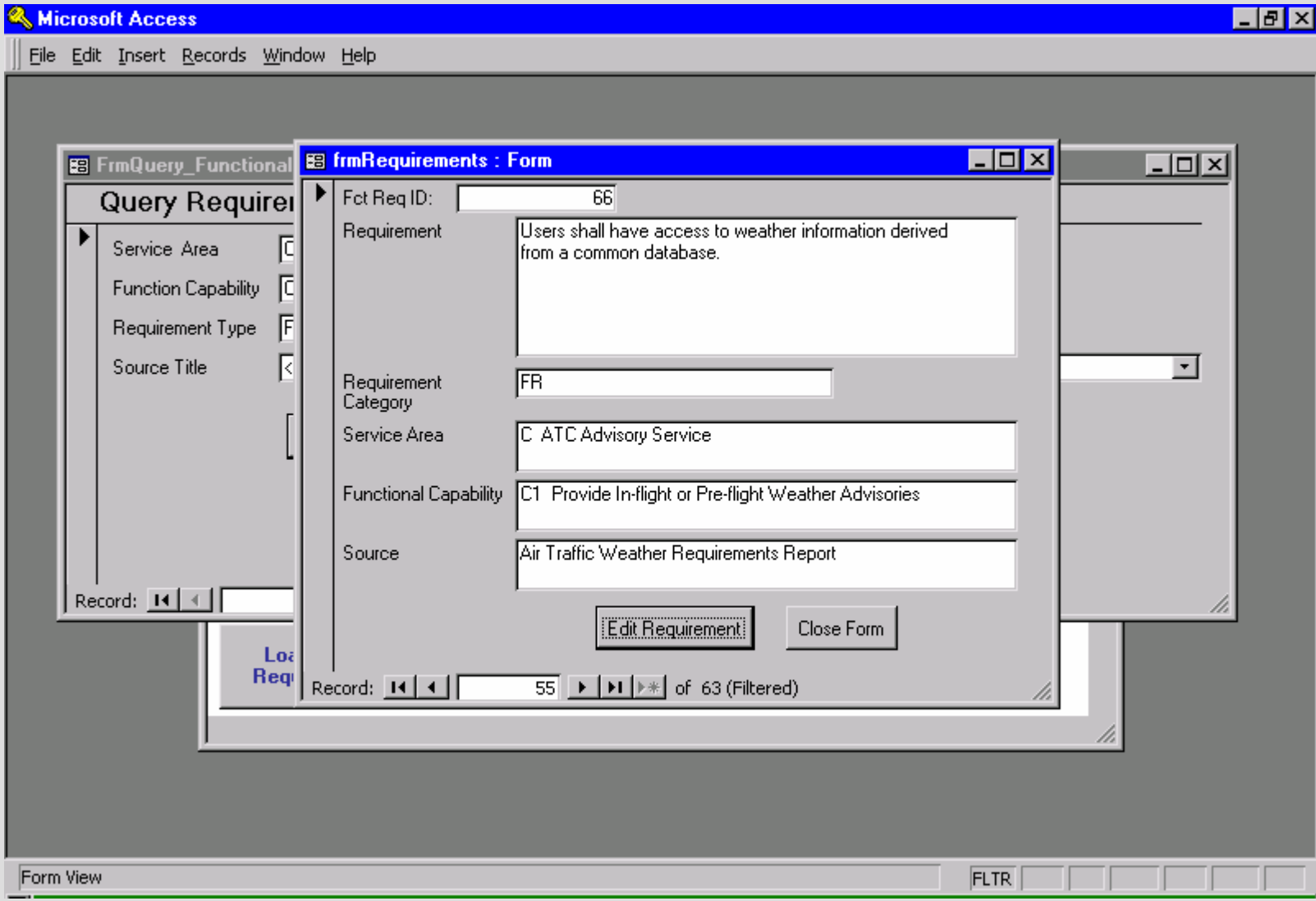
Requirements Database

Functional Communications Requirements

Airspace Users	Message Characteristics
Functional Capabilities	Communications Requirements NAS
Service Architecture	Delay, Availability, Integrity
System Level Requirements	Source Traceability

Database Screen

User Friendly Forms



Task 4 developed a common base for architecture concepts.

Task 4
Preliminary Candidate Comm. System Architecture Concepts

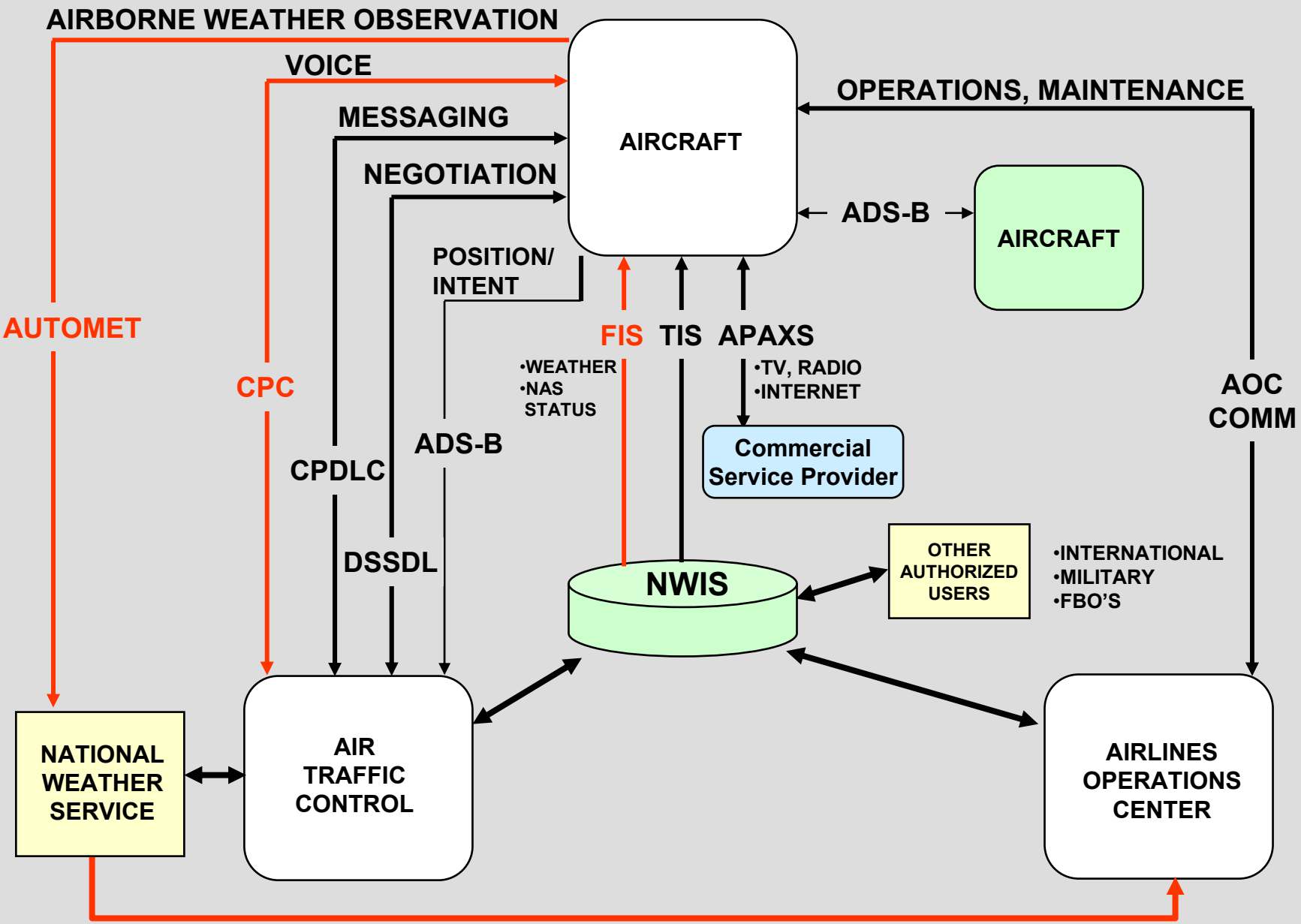
Mature to Present (Top Down)

Benefits Driven (Based on Equipage)

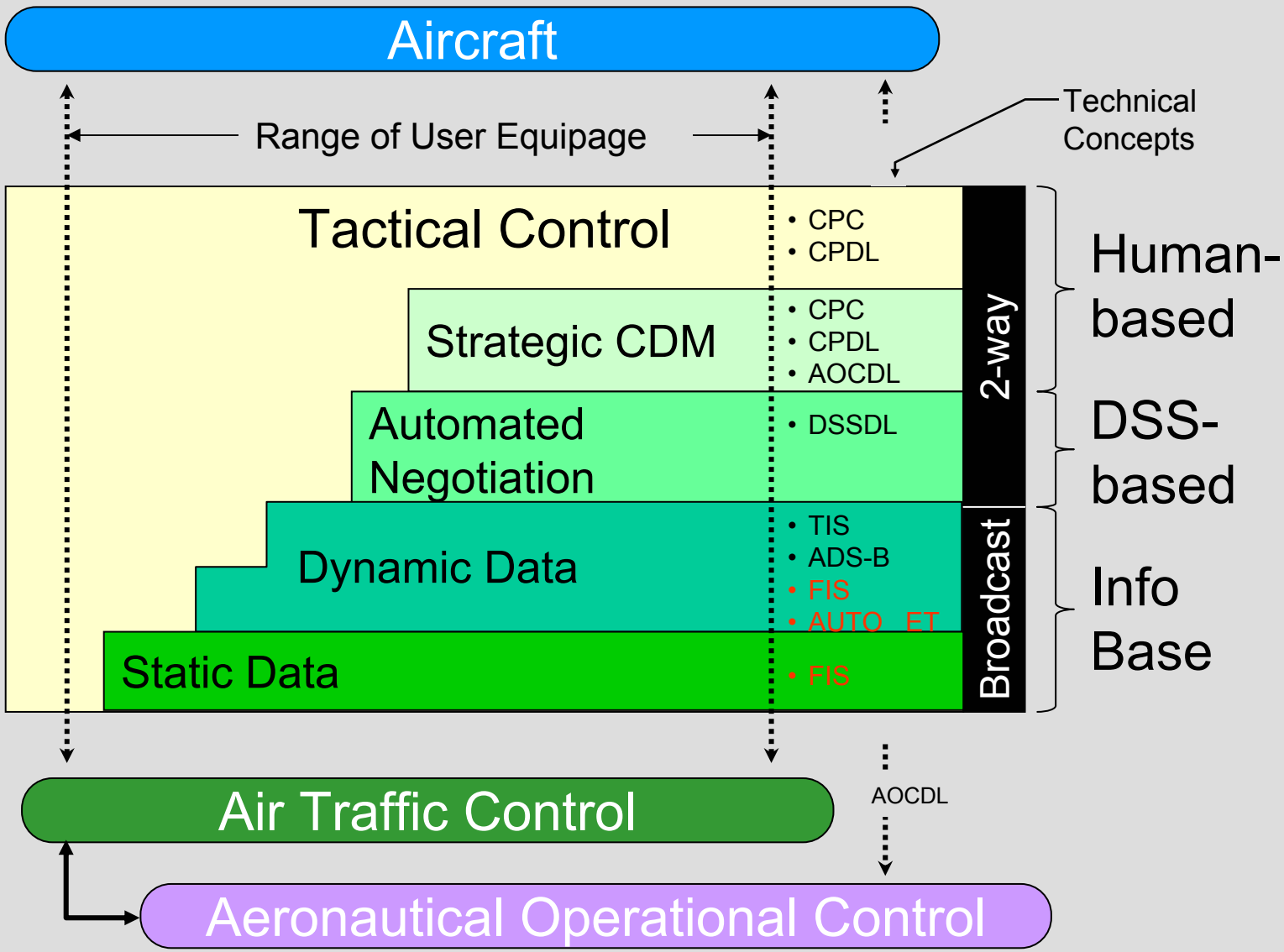
Evolutionary Path

Architecture Selection Challenges

Air-Ground Comm Functional Architecture



Benefits Driven Concept



Architecture Selection Challenges

- Conflicting Report Data - contributes to load estimate uncertainty
  - Air Traffic forecasts
  - Message definition, size, and frequency
- Selection of Hybrid Architecture should be driven by Cost, Schedule, or Performance considerations
  - Cost not a consideration for this task
  - 2007 Schedule not a driver - given no cost constraints
  - Performance - function of a selected link - many unknowns
    - ADS-B link decision - can have major impact on architecture selection
    - SATCOM implementation - driven by commercial cabin services (could lead to class 1 Avionics cost/performance issues)
    - FIS-B implementation - commercial design implementation can drive overall architecture

Task 5 AATT
2015 Architecture

Task 6 AATT
2007 Architecture

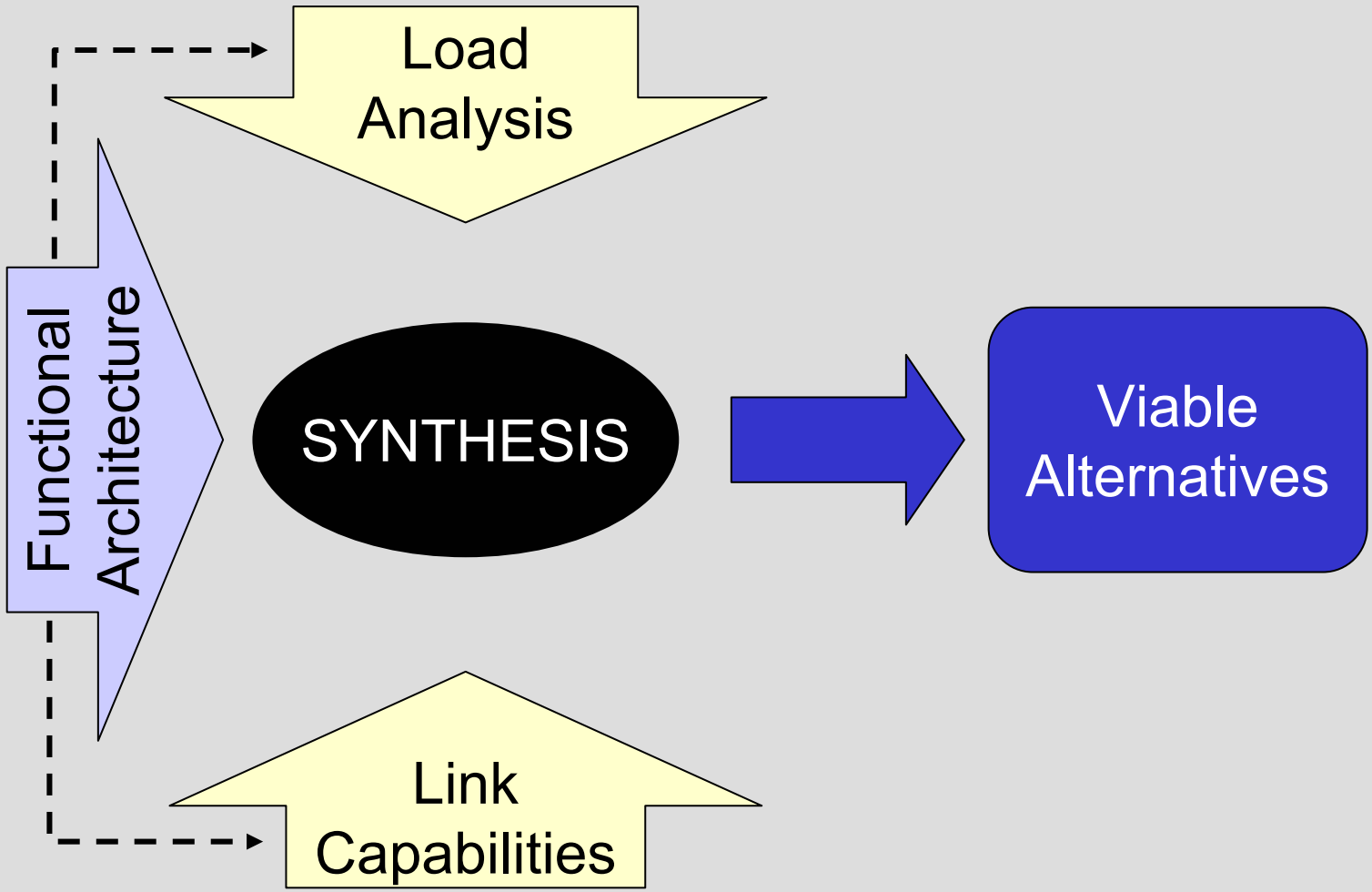
Task 7 AWIN
2007
Architecture

Begin with 2015 Analysis

2015 AATT Mature State Drives 2007 AATT

2007 AWIN analysis conducted in context of 2007

Process


Load
Analysis
Functional
Architecture
SYNTHESIS
Viable
Alternatives
Link
Capabilities

Functional Analysis

- 9 Technical Concepts
- Defined Message categories and message types for each Technical Concept
- Concept Description
- Concept Diagram

Operational Concept - Tech Concept

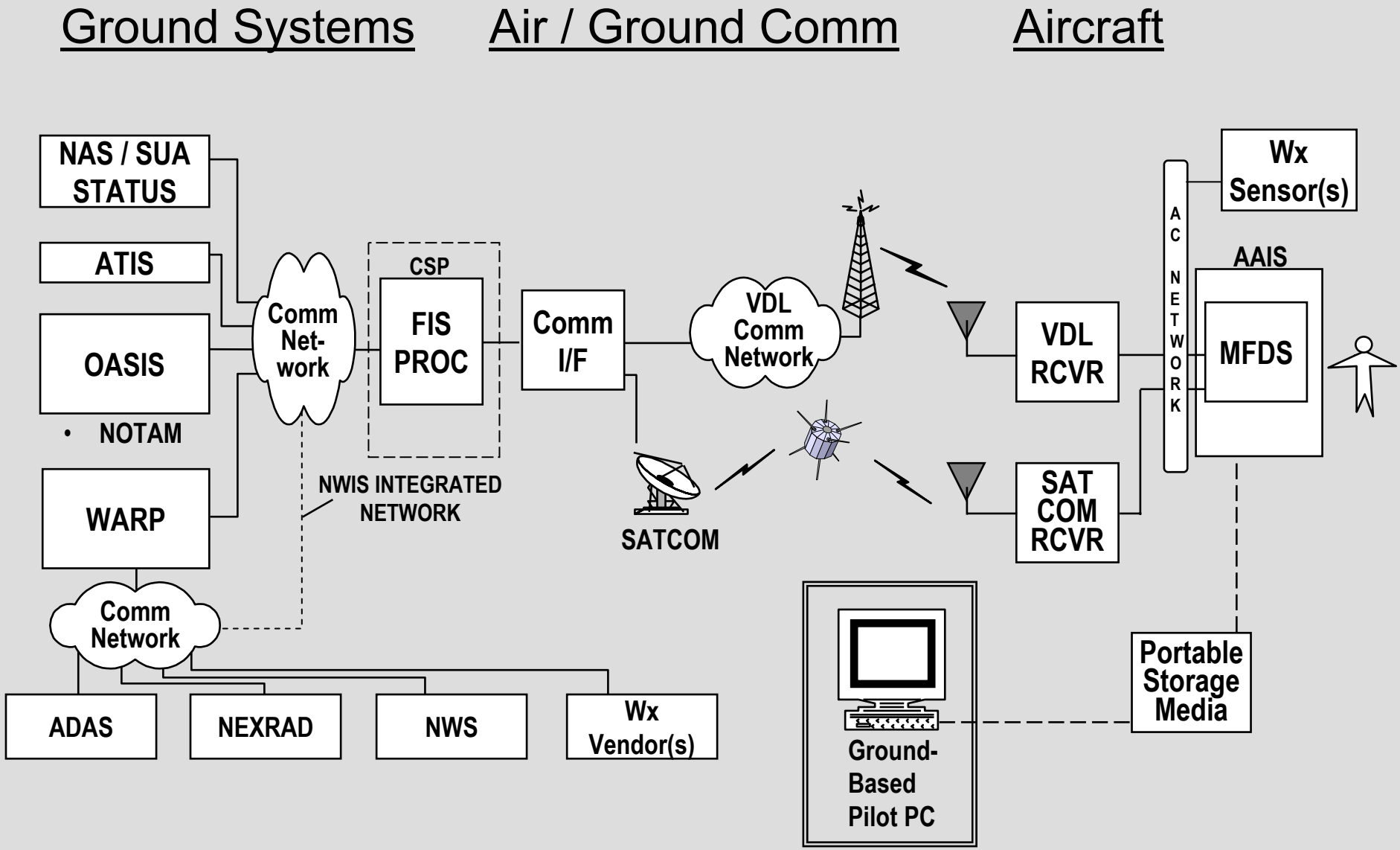
Operational Concept	Technical Concept
Aircraft continuously receive Flight Information to enable common situational awareness	Flight Information Services (FIS)
Aircraft continuously receive Traffic Information to enable common situational awareness	Traffic Information Services (TIS)
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	Controller-Pilot Data Link Communications (CPDLC)
Controller - Pilot voice communication	Controller Pilot Communications (CPC)
Aircraft exchange performance / preference data with ATC to optimize decision support	Decision Support System Data Link (DSSDL)
Aircraft continuously broadcast their position and intent to enable optimum maneuvering	Automated Dependent Surveillance-Broadcast (ADS-B)
Pilot - AOC messaging supports efficient air carrier/air transport operations and maintenance	Airline Operational Control Data Link (AOCDL)
Aircraft report airborne weather to improve weather nowcasting/forecasting	Automated Meteorological Transmission (AUTOMET)
Passengers enjoy in-flight television, radio, internet, and entertainment service	Aeronautical Passenger Services (APAXS)

Concept Description - Flight Information Service

- Aircraft continually receive dynamic Flight Information to enable common situational awareness
  - Weather Information
  - NAS Status
  - NAS Traffic Flow Status

Note: We assume that static data will be loaded on aircraft via portable storage media prior to flight.

2015 Flight Information Service - FIS



FIS Products

Primary Source: Data Communications Requirements, Technology and Solutions for Aviation Weather Information Systems (Phase I Report), Lockheed Martin Aeronautical Systems 1999.

Assumptions:

- Projected weather products are bit-mapped pictures in a multi-dimensional grid.
- Broadcast weather products represent computer generated, synthesized, integrated information.
- These products represent generic projections of products that will be available five to 10 years in the future.

Secondary Source: RTCA DO 237, Aeronautical Spectrum Planning, 1997

2015 FIS Load Analysis Results

2-way

- Worst case scenario: En Route airspace with high density Terminal area and four major Airports

	Airport	Terminal	En Route	Total
FIS - Domain	36.4	135	1092	
Region (x) [1]	145.6 (4)	135 (1)	1092 (1)	1372.6

Note: (x) is domain multiplier

(K-bits per second)

Broadcast

- Regional scenario: En Route airspace with 5 Terminal/Airport areas

	Airport	Terminal	En Route	Total
FIS - Domain	0.2	0.9	6.9	
FIS - Region	1.0 (5)	4.5 (5)	6.9 (1)	12.4
FIS - National				248 (20)

Note: (x) is domain multiplier

(K-bits per second)

2015 FIS Viable Alternatives

- ✈Broadcast is preferable for FIS
- ✈VDL-B can support a regional broadcast of FIS data
  - – Allocation of only 2 frequencies per CSP poses coverage / interference problems for National implementation
- ✈UAT, SATCOM can support Regional and National implementation

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Flight Information to enable common situational awareness	FIS					✓		✓	✓	
✓ Acceptable Alternative		NAS Architecture				★ Restricted Operation				

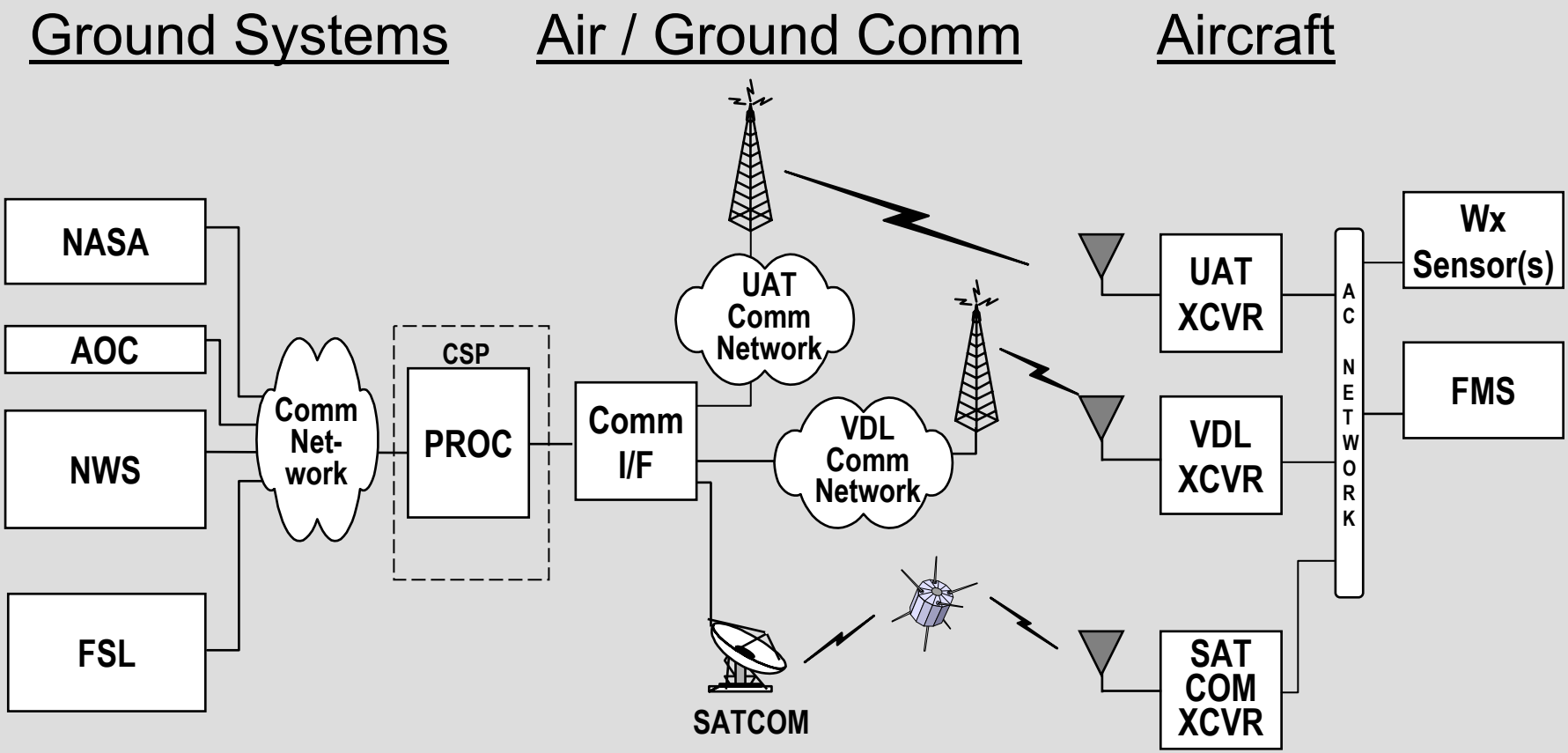
Concept Description - Automated Meteorological Transmission

- Aircraft report airborne weather data to improve weather nowcasting/forecasting.

  Also know as...
  - MDCRS, E-MDCRS [NOAA, NWS]
  - ACARS [NOAA, FSL]
  - EPIREPS [NASA]

- AUTOMET definition is currently under the auspices of the RTCA SC 195
  - Minimum Interoperability Standards (MIS) for Automated Meteorological Transmission (RTCA DO-252)
  - wind, temperature, water vapor and turbulence.

Automated Meteorological Transmission - AUTOMET



2015 AUTOMET Load Analysis Results

- AUTOMET message contains
  - Wind
  - Temperature
  - Humidity
  - Turbulence
- Message size and frequency based on 1999 RTCA MIS
- Assume no AUTOMET in Airport Domain
- Worst case scenario: En Route airspace with high density Terminal area

	Airport	Terminal	En Route	Total
AUTOMET	N/A	4.4	6.2	
Worst Case	N/A	4.4 (1)	6.2 (1)	10.6

Note: (x) is domain multiplier

(K-bits per second)

2015 AUTOMET Viable Alternatives

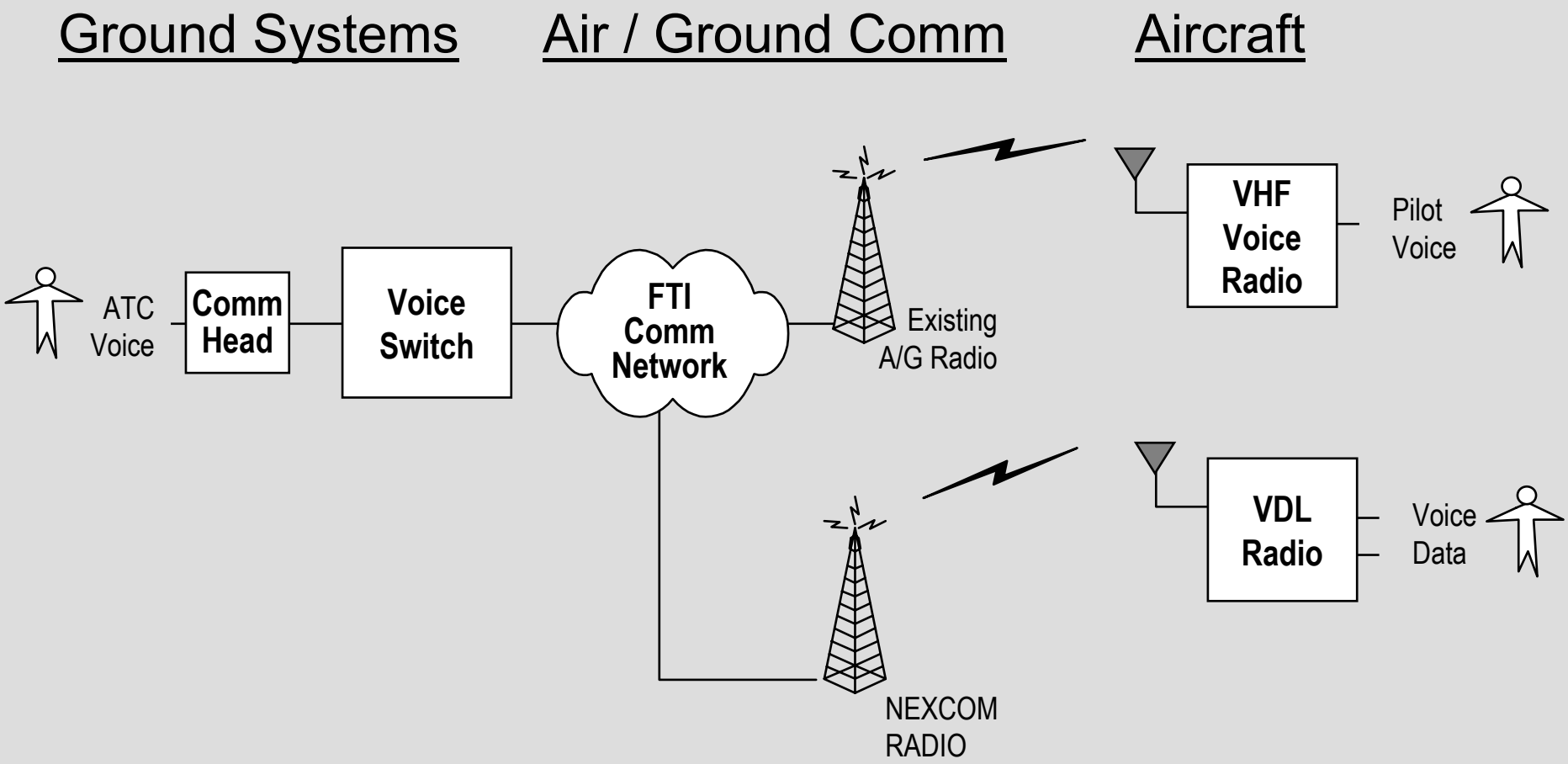
- ✈AUTOMET type data currently delivered via ACARS network
- ✈Assume transition to VDL-2 network
- ✈VDL-2 national network operated by CSP since 2001
- ✈VDL-2 single frequency effective data rate is 19.2 kbps.
  - 4 frequencies used for AOCDL - 76.8 kbps
  - This is sufficient to support the projected demand
- ✈UAT, SATCOM could support the load requirement
  - Unlikely use if existing network can support requirement

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft report airborne weather to improve weather nowcasting/forecasting	**AUTOMET**		**3**					**3**		**3**
3 Acceptable Alternative		NAS Architecture								

Concept Description - Controller/Pilot Voice Communication

- CPC supports tactical control and strategic CDM.
- CPC communication remains the foundation of air traffic control.
- It is critical to maintain a high quality, robust voice communication service.
- Digitized voice service can be combined with data service provided QOS is maintained

2015 - CPC Controller/Pilot Voice Communication



2015 CPC Load Analysis Results

- In 2015 most routine messages are sent via CPDLC
  - Clearance Delivery
  - Transfer of Communication
  - Initial contact
  - Altimeter
- Our Analysis assumed an average of 1.5 call-seconds per minute per flight

Class	Airport		Terminal		En Route	
	Uplink	Downlink	Uplink	Downlink	Uplink	Downlink
1	2.7	1.3	0.7	0.7	2.0	0.5
2	0.9	0.4	0.3	0.3	0.2	0.1
3	1.2	0.5	0.0	0.0	0.0	0.0
Total	7.0		1.9		2.7	
Voice Channels Required (P=0.2)	10		4		5	

Call-seconds per second

2015 CPC Viable Alternatives

- Our communication load analysis indicates that a single VDL-3 sub-channel is sufficient to support controller pilot communication under worst case loading conditions.

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Controller - Pilot voice communication	CPC	✓		✓						
✓ Acceptable Alternative		☐ NAS Architecture				★ Restricted Operation				

2015 Architecture Alternatives Summary

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Flight Information to enable common situational awareness	**FIS**					✓		✓	✓	
Aircraft continuously receive Traffic Information to enable common situational awareness	**TIS**					✓		✓	✓	
Controller - Pilot Communication	**CPC**	✓		✓						
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	**CPDLC**			✓						
Aircraft exchange performance / preference data with ATC to optimize decision support	**DSSDL**			✓						
Aircraft continously broadcast their position and intent to enable optimum maneuvering	**ADS-B**				✓		✓	✓		
supports efficient air carrier/air transport operations and maintenance	**AOCDL**		✓					✓		✓
Aircraft report airborne weather to improve weather nowcasting/forecasting	**AUTOME**		✓					✓		✓
Passengers enjoy in-flight television, radio, telephone, and internet service	**APAXS**								✓	✓

✓ Acceptable Alternative

NAS Architecture

AATT CSA Recommendation

Top Down vs Bottom Up Architecture

- Top Down Architecture optimizes at the “system” level
  - May contain sub-optimal solutions for 1 or more sub-systems
  - For this task: Minimize the number of radio’s on the aircraft and the ground infrastructure
- Bottom Up Architecture optimizes at the “sub-system” level
  - Optimizes each sub-system without regard to total system
  - For this task: Select optimum radio

Top Down Observations

- Human / DSS ATC interfaces satisfied by VDL-3 Link - NAS Architecture Baseline
  - CPC
  - CPDLC
  - DSSDL

(K-bits per second)

	Airport	Terminal	En Route
CPC	1 voice channel per sector		
CPDLC	6.3	2.2	2.4
DSSDL	0.5	0.3	0.2
Total	6.8	2.5	2.6

- Human / AUTOMET AOC interfaces satisfied by VDL-2 Link - Consistent with current planning, Not in NAS Arch
  - AOCDL
  - AUTOMET

	Airport	Terminal	En Route
AOCDL	8.8	9.1	3.7
AUTOMET	N/A	4.4	6.2
Total	8.8	13.5	9.9

- Dynamic Information Base satisfied with Broadband Link - No integrated plan for NAS Broadband data
  - FIS
  - TIS
  - ADS-B

	Region
FIS	12.4
TIS	55.5
ADS-B	20.9

- Broadband data solution can be Terrestrial or Space Based

Broadband Data Considerations

- ADS-B link decision - can have major impact on Terrestrial vs Space based decision
- SATCOM implementation - driven by commercial cabin services (could lead to class 1 Avionics cost/performance issues)

	UAT	SATCOM
Base	• Terrestrial • FAA Radar, Navigation and/or Air-Ground Communication sites	• Space • Assume desirable CONUS coverage • Commercial service providers
Capacity	1Mbps	≥ 2Mbps
PRO's	– If selected as ADS-B link, all aircraft would eventually have UAT radio – Use of FAA sites – Avionics design complete – standards in development	• CONUS coverage without maintenance of terrestrial network • Higher data rates • Most likely will be available from commercial service providers
CON's	– Maintenance of terrestrial network – Additional radio required if not selected as part of ADS-B	• Immature avionics design - no standards – unproven for small GA aircraft • Additional radio required for non-APAXS equipped users

2015 Top Down Architecture - SATCOM Data

Ground		Link	Aircraft
FTI Network	NEXCOM Site	VDL-3	Primary 2-way CPC / CPDLC / DSSDL
CSP Interface	CSP Network	VDL-2	Secondary 2-way AOC / AUTOMET
FTI Network	CSP Network	SATCOM	Data Receive FIS / TIS / APAXS
FTI Network	ADS-B Site	UAT VDL-4 Mode-S	Data Transmit ADS-B

Not analyzed as part of this task

Augmentation Network		WAAS / LAAS	Navigation Rcvr WAAS / LAAS / VOR
	VOR Site	VOR	
FTI Network		Mode-S	Surveillance Xpndr Separation / TCAS

2015 Top Down Architecture - UAT Data

Ground		Link	Aircraft
FTI Network	NEXCOM Site	VDL-3	Primary 2-way CPC / CPDLC / DSSDL
CSP Interface	CSP Network	VDL-2	Secondary 2-way AOC / AUTOMET
FTI Network	CSP Network	UAT	Data Receive FIS / TIS
FTI Network	ADS-B Site	UAT	Data Transmit ADS-B
CSP Network		SATCOM	APAXS

Not analyzed as part of this task

Augmentation Network		WAAS / LAAS	Navigation Rcvr WAAS / LAAS / VOR
	VOR Site	VOR	
FTI Network		Mode-S	Surveillance Xpndr Separation / TCAS

Interim Architecture Development

- 2007 AATT Architecture driven by 2015 AATT Architecture
  - Multiple Communication Solutions exist - pick solutions on the path to 2015 AATT
- 2007 AWIN Architecture part of the 2007 AATT Architecture
  - FIS
  - AUTOMET
  - CPC

2007 AATT CSA

- Human voice communications satisfied by VHF-AM
  - CPC: Transition to VDL-3
- ATC data message interfaces satisfied by VDL-2 Link - NAS Architecture Baseline
  - CPDLC: Transition to VDL-3
  - DSSDL: Transition to VDL-3
- Human / AUTOMET AOC interfaces satisfied by VDL-2 Link - No change from 2015, Not part of NAS Architecture
  - AOCDL
  - AUTOMET
- Dynamic Information Base satisfied with Multiple Links - No integrated plan for NAS Broadband data
  - FIS: CSP supports VDL-B and Broadband solution
  - TIS: Broadband solution
  - ADS-B: Follow ADS-B link decision

2007 Architecture Alternatives Summary

Operational Concept	Technical Concept	VHF-AM	VDL-2/ ATN	VDL-3/ ATN	VDL-4/ ATN	VDL-B	Mode-S	UAT	SATCOM-Broadcast	SATCOM-2way
Aircraft continuously receive Flight Information to enable common situational awareness	**FIS**					✓		✓	✓	
Aircraft continuously receive Traffic Information to enable common situational awareness	**TIS**					✓		✓	✓	
Controller - Pilot voice communication	**CPC**	✓								
Controller - Pilot messaging supports efficient Clearances, Flight Plan Modifications, and Advisories (including Hazardous Weather Alerts)	**CPDLC**		✓							
Aircraft exchange performance / preference data with ATC to optimize decision support	**DSSDL**		✓							
Aircraft continously broadcast their position and intent to enable optimum maneuvering	**ADS-B**				✓		✓	✓		
supports efficient air carrier/air transport operations and maintenance	**AOCDL**		✓					✓		✓
Aircraft report airborne weather to improve weather nowcasting/forecasting	**AUTOMET**		✓					✓		✓
Passengers enjoy in-flight television, radio, telephone, and internet service	**APAXS**								✓	✓

✓ Acceptable Alternative

NAS Architecture

AATT CSA Recommendation

2007 Architecture - SATCOM Data

Ground		Link	Aircraft
FTI Network	NEXCOM Site	VHF-AM	CPC - Voice
CSP Interface	CSP Network	VDL-2	Secondary 2-way CPDLC / DSSDL AOC / AUTOMET
FTI Network	CSP Network	VDL-B	FIS - Regional
		SATCOM	FIS / TIS / APAXS
FTI Network	ADS-B Site	UAT VDL-4 Mode-S	Data Transmit ADS-B

Not analyzed as part of this task

Augmentation Network		WAAS / LAAS	Navigation Rcvr WAAS / LAAS / VOR
	VOR Site	VOR	
FTI Network		Mode-A/C/S	Surveillance Xpndr Separation / TCAS

2007 Architecture - UAT Data

Ground		Link	Aircraft
FTI Network	NEXCOM Site	VHF-AM	CPC - Voice
CSP Interface	CSP Network	VDL-2	Secondary 2-way CPDLC / DSSDL AOC / AUTOMET
FTI Network	CSP Network	VDL-B	FIS - Regional
		UAT	FIS / TIS
FTI Network	ADS-B Site		Data Transmit ADS-B
CSP Network		SATCOM	APAXS

Not analyzed as part of this task

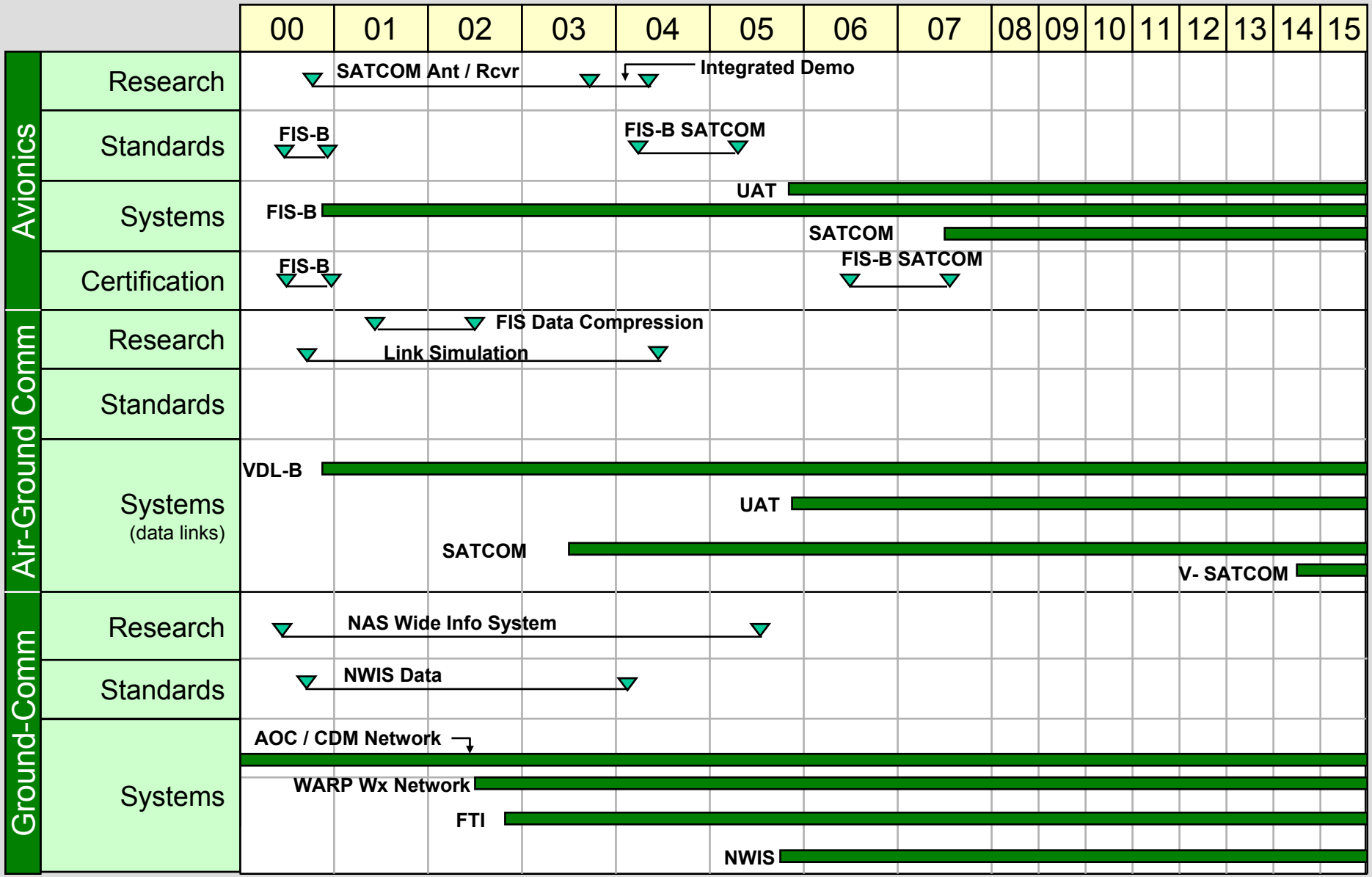
Augmentation Network			Navigation Rcvr WAAS / LAAS / VOR
	VOR Site	VOR	
FTI Network	Radar Site	Mode-A/C/S	Surveillance Xpndr Separation / TCAS

TASK 8

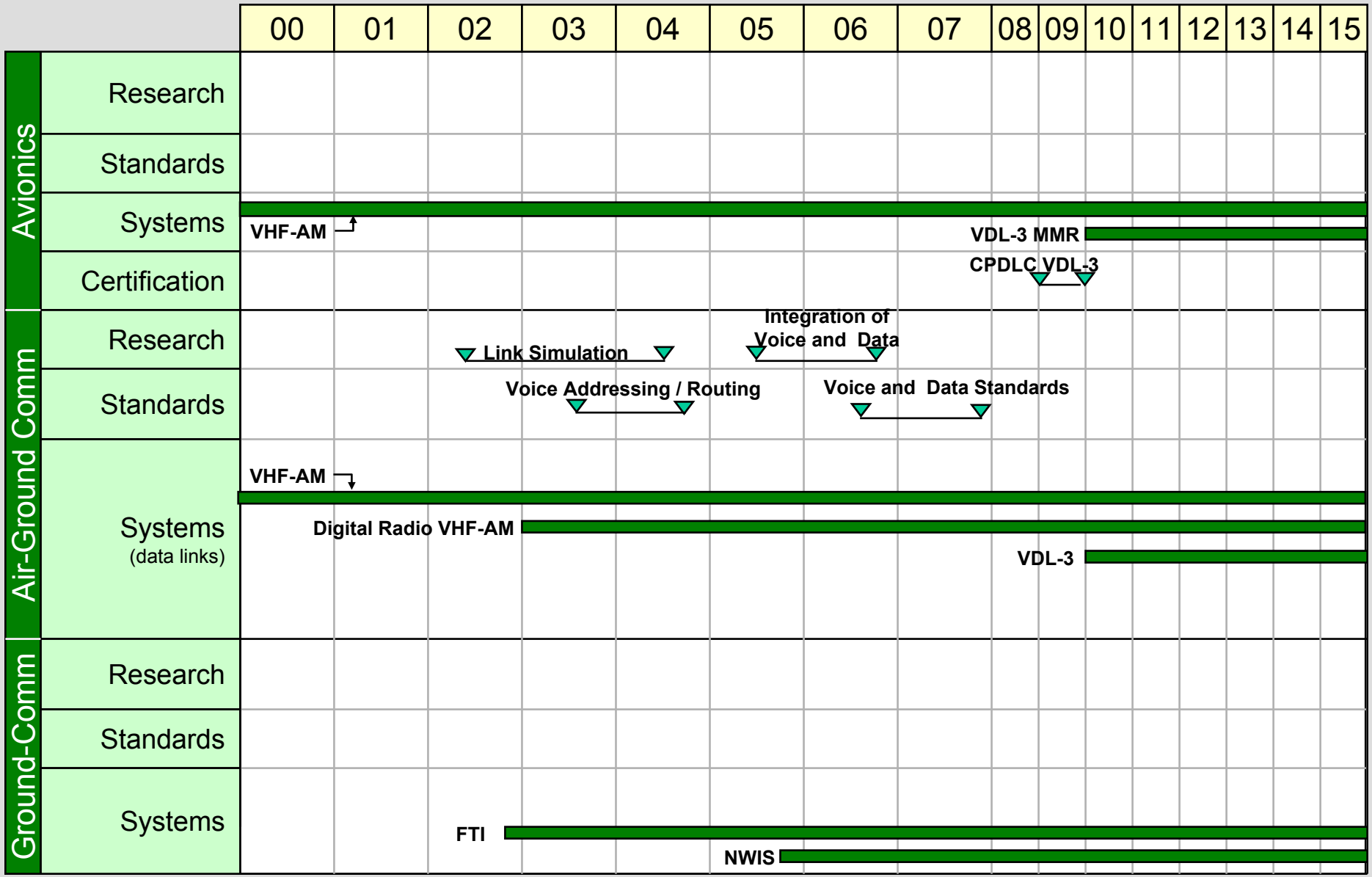
Transition

Defines the key milestones and activities for implementation of each of the technical concepts and communications links.

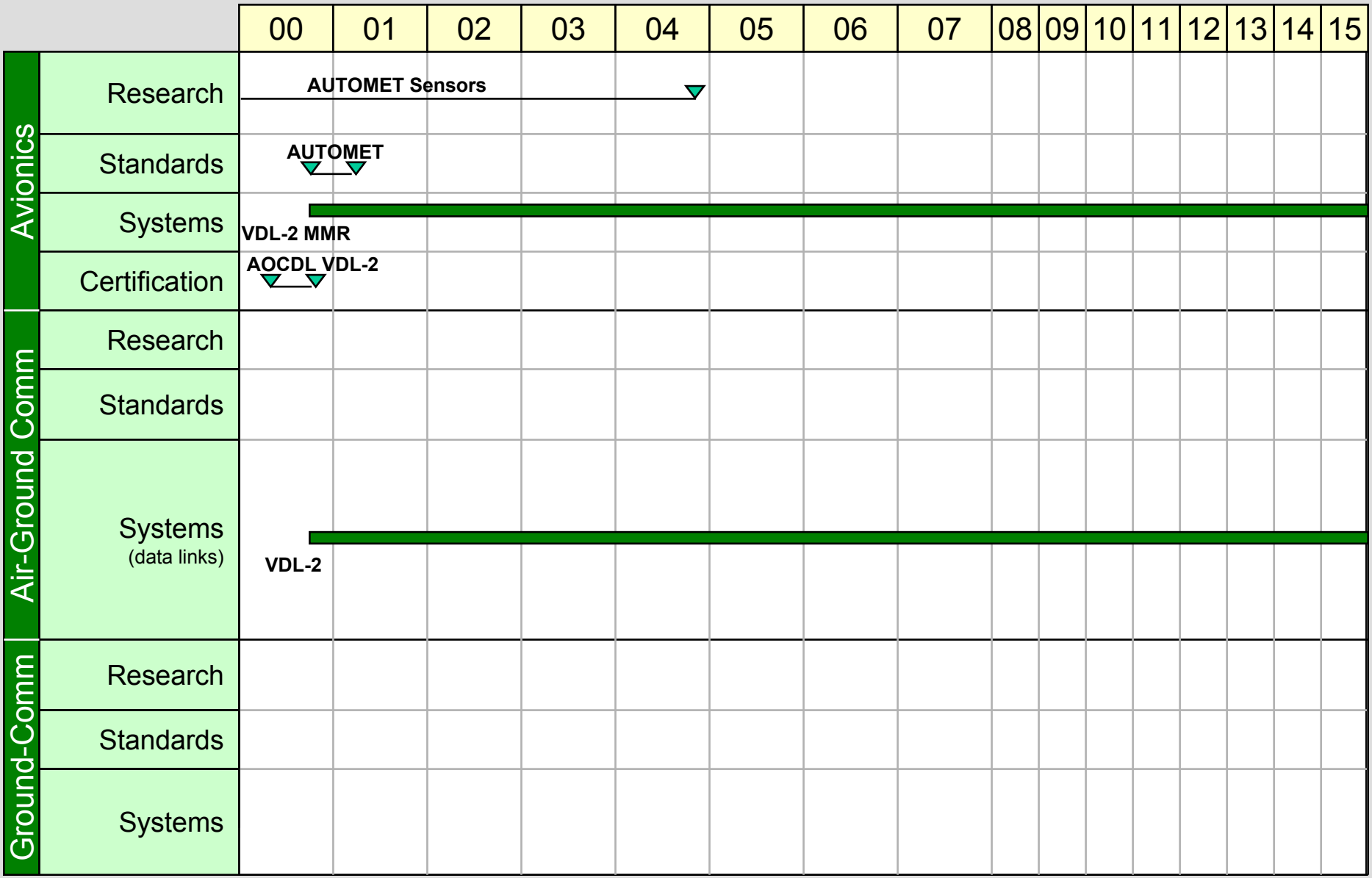
AATT Communication Architecture Schedule - FIS



AATT Communication Architecture Schedule - CPC



AATT Communication Architecture Schedule - AUTOMET



Communications Technology Gaps, Solution Alternatives and Areas for R&D Tasks 10 & 11

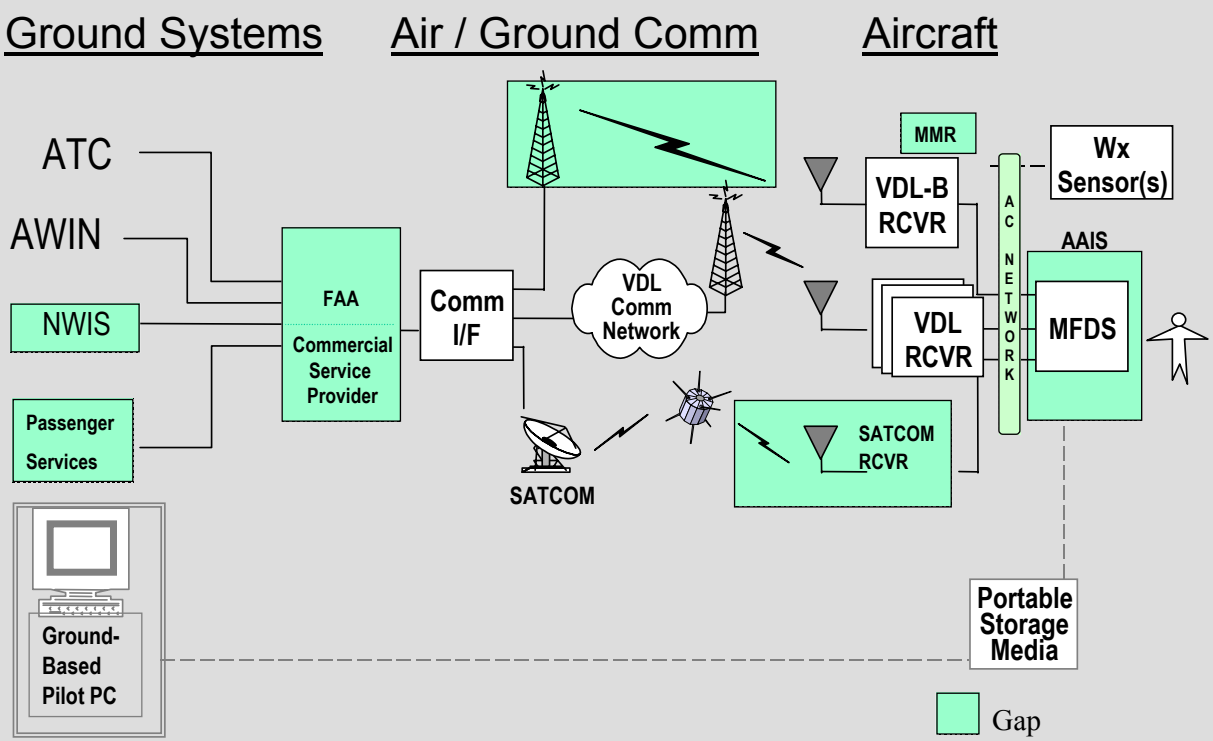
May, 2000

AATT TO24
SAIC Team

Communications Technology Gaps & Solution Alternatives

Task 10

Task 11



AATT TO 24 Challenges

- Evolving Standards, concepts, product definitions, communications technologies and services (AUTOMET, EPiRep, VDL-B, UAT, VDL -4)
- Variations and inconsistencies in documented message traffic and aircraft projections
- Pending link decisions that could impact recommendations (ADS-B)
- Concept definitions (NWIS, DAG)
- Market drivers (APAX)

AATT TO24 Accomplishments

- Provided a framework for future decision making
- Provided a coherent structure for future research and analysis
- Collected, sorted and categorized input from multiple reports
- Provided traceability from user requirements to services and communications links through the use of functional capabilities and technical concepts
- Developed a repository for continued data collection
- Determined viable links for each service from a top down and bottom up perspective
- Identified key milestones for transition to 2015 AATT CSA
- Identified gap areas and solution candidates for further research

AATT TO 24 Status

- Individual Task Reports Delivered:

  July 99-May 00

- AATT TO24 Team Presentations:

  May, July, September, October, 1999

  January, February, March, 2000

- Final Presentation:

  May 10-11, 2000

- Final Report:

  May 26, 2000

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